Microwave Signal Mixing by Using a Fiber-Based Optoelectronic Oscillator for Wavelength Division Multiplexed (WDM) Systems

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Two WDM channels at 1320 nm and 1312 nm carrying RF signals are simultaneously up/down converted by a fiber-based optoelectronic oscillator. The conversion efficiency are found (o be- -8 dB and the incoming signals has no effects on the local oscillator spectral purity.

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Fiber optics has been rapidly penetrating into the microwave systems as the advancement of the optical component technology. In additional to microwave transmission for subcarrier systems [1] and satellite communications [2], many new capabilities have been demonstrated such as microwave generat ion, filtering and mixing, which arc traditional 1 y performed by the microwave electronics. Additionally, emerging wavelength division multiplexing (WDM) technology not only finds its place in increasing the system capacity, but also in microwave signal processing such as true time delay control for phased array antenna systems [3]. A novel microwave fiber-optic link has been proposed where the information data is up/down converted by two external modulators [4]. Such a scheme offers advantage of avoiding the need of high speed photodetectors and microwave mixers. However, one difficult task remains that the electrical local oscillator (LO) is still needed. The high frequency LO is generally obtained by multiplying a low frequency standard through numerous stages of multipliers and amplifier-s, which is bulky and cumbersome. Recently, a ncw kind of a fiber-based photonic oscillator- has been proposed and demonstrated [5]. Such an oscillator can generate microwave with high spectral purity up to 75 GHz and many interesting capabilities such as subcarrier/clock recovery and microwave regeneration have been demonstrated [5]. Wc propose a ncw function for this microwave oscillator, namely, photonic microwave mixing for WDM systems [Fig. 1a]. In this approach, WDM channels carrying RF signals arc simultaneously down converted to IF frequencies by a fiber-based local oscillator, and detected by a low speed detector array. In the demonstration, the RF signals carried on the wavelengths of 1320 nm and 1312 nm are simultaneousl y down/up converted by the photonic oscillator at - 5 GHz. The conversion efficiency is found to be -8 dB and the local oscillator spectral purity is not affected by the incoming signals.

The optoelectronic oscillator is basically a microwave delay line with the open loop gain larger than 1 [fig. 1 b], The oscillator loop consists of the optical pumping light being modulated by an external modulator, transmitted by a fiber delay line, detected by a photodetector, electrically amplified and fed back into the modulator RF drive port. Just as a fiber-based ring laser, utilizing a fiber delay offers the advantage of an effective high-Q which results superior RF spectral purity. Using the local oscillator as a mixer eliminates the problems of RF isolation and RF power sharing between the modulator and the local oscillator. Although a high speed detector and a modulator are used in the local oscillator, the cost is highly justified by the resulting spectral purity of the RF signal generated by this approach, especially for the high frequency in millimeter wave range. Fig. 1b also shows the experimental setup. Two optical signals at 1320 nm and 1312 nm are modulated at around 6 GHz with frequencies 50 MHz apart. The combined signals are used to simulate the WDM signals which will be processed by the optoelectronic oscillator. The pump for the oscillator is at 1543 nm. The power into the modulator is -6.6 dBm, -4.5 dBm and 6 dBm for 1320 nm, 1312 nm and 1543 nm respectively. The output from one port of the modulator is coupled into the oscillator loop and passes through a 1.5 μm filter which attenuates 1.3 μm signals with a 60 dB rejection ratio. The output from the other port is detected and monitored by an RF spectrum analyzer. The fiber delay of the oscillator is about 1 km and the mode selection is done by electrically injecting -50 dBm RF signals at 5.1'1 GHz. The resulting signal-to-side-mode ratio of the RF signal of the local oscillator is over 65 dB.

Figures 2a, 2b and 2c show the measured RF spectra at the output of the local oscillator. Fig. 2a shows the two unconverted RF signals around -6 GHz. Fig. 2b shows the down converted signals around -800 MHz. Fig. 2c shows the up converted signals around 11 GHz. The input power into the optical detector are -13.8 dBm and -11.50 dBm for 1320 nm and 1312 nm respectively. The RF power from detector is amplified by about 20 dB.

Figure 3 shows the performance of the oscillator. Fig. 3a shows the performance as a mixer. We plot the RF power of the converted signal as a function of the RF power of the unconverted signal. The change of the RF power of the unconverted signal is obtained by changing the RF modulation power to either 1320 nm or 1312 nm lasers. The conversion is very linear and nearly 1 dB increase of the unconverted signal power results in 1 dB increase of the converted signal. There is around 4 dB difference between up-converted and down-converted signals. This is mainly due to the response of the optical detector and the RF cable. Furthermore, the results for these two wavelengths (1320 nm and 1312 nm) are almost identical, implying the perfect operation for the WDM systems. Most significantly, the conversion efficiency (the ratio between the converted signal and the unconverted signal) is around -8 dB, only 2 dB penalty in comparison to a perfect conversion which is -6 dB. Note that only -50 dBm RF power is injected and the open loop RF power at the modulator for this injection signal is 12 dBm. However, the oscillation RF power at the modulator is 25 dBm, implying a 13 dB RF gain for this oscillator. Also the phase noise due to the electrical amplifier is greatly reduced by this high-Q fiber microwave delay line. Finally, the oscillator itself is not affected by processing the signals because they are effectively rejected by the optical filter. Fig. 3b shows the spectrum of the oscillator and we found no visible difference whether the WDM signals are injected or not.

Figure Captions

I. (a) Conceptual diagram of the new function of the fiber optoelectronic oscillator, (b) Experimental setup

2.. Measured RF spectrum for (a) input RF signals around 6 GHz, (b) down-converted signals around 800 MHz, and (c) up-converted signals around 11 GHz. Both RBW and VBW arc 10 kHz.

3. Performance of the oscillator: (a) the RF power of the converted signal as a function of the RF power of the unconverted signal, and (b) the spectrum of the local oscillator for the cases (1) the signals are not injected, (2) the signals are injected.

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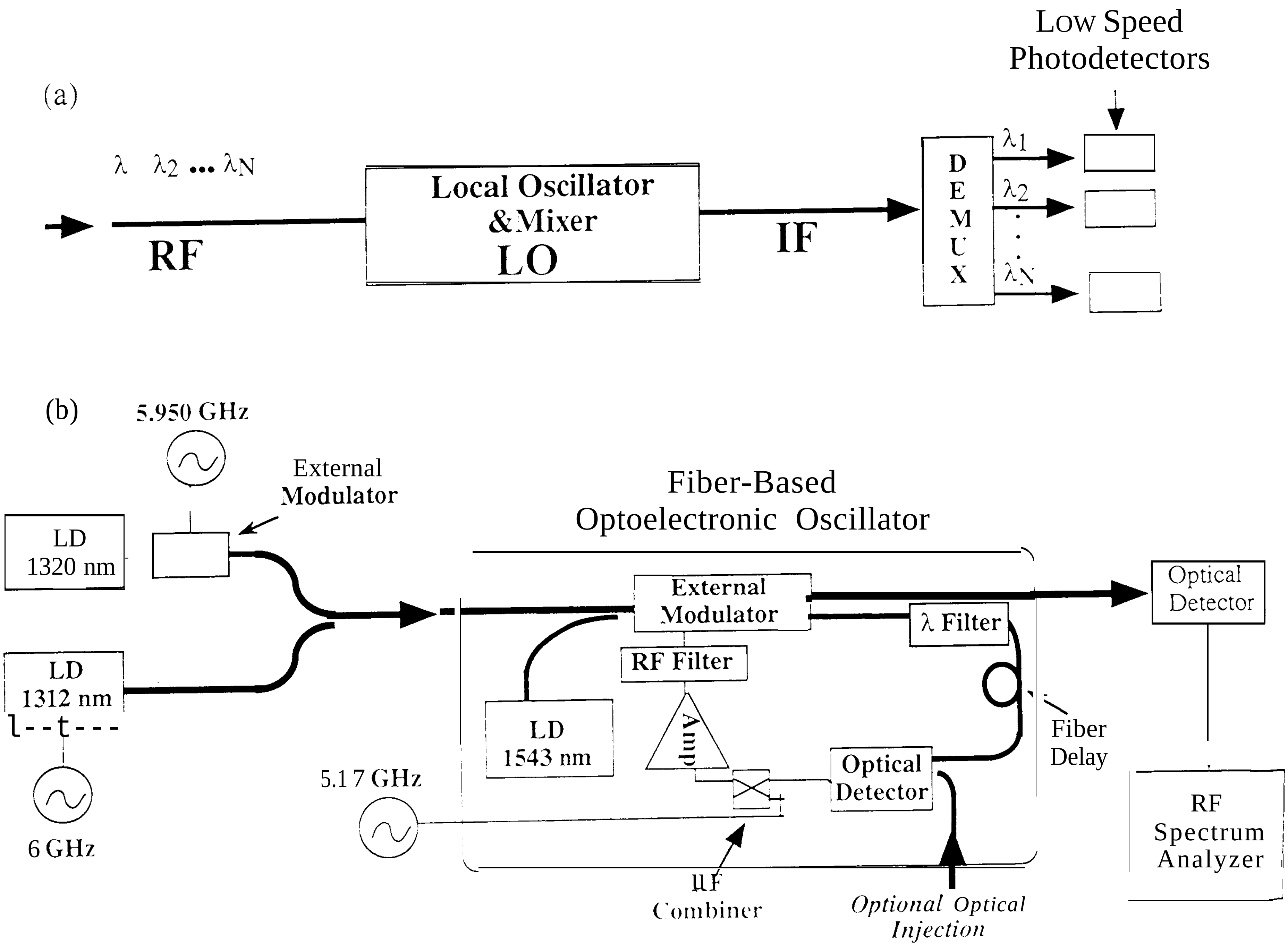

(a)
Low Speed
Photodetectors
λ λ2 ... λN
Local Oscillator
&Mixer
LO
RF
IF
D
E
M
U
X
λ1
λ2
λN
(b)
5.950 GHz
External
Modulator
LD
1320 nm
LD
1312 nm
6 GHz
Fiber-Based
Optoelectronic Oscillator
External
Modulator
λ Filter
RF Filter
LD
1543 nm
Amp
Optical
Detector
Fiber
Delay
5.17 GHz
Combiner
Optional Optical
Injection
Optical
Detector
RF
Spectrum
Analyzer

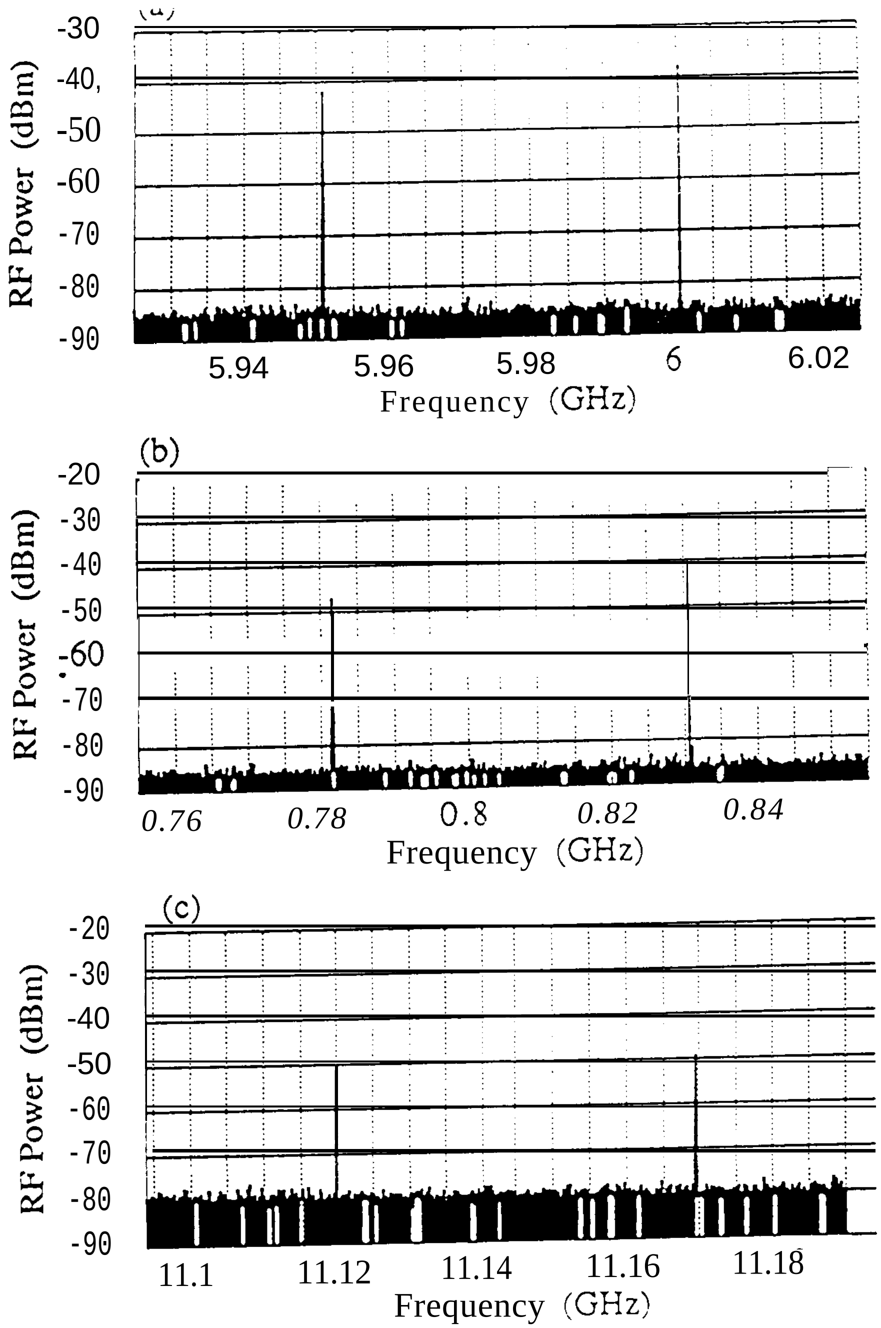
(b)
(c)
RF Power (dBm)
-30
-40
-50
-60
-70
-80
-90
5.94
5.96
5.98
6
6.02
Frequency (GHz)
-20
0.76
0.78
0.8
0.82
0.84
11.1
11.12
11.14
11.16
11.18

Figure 2

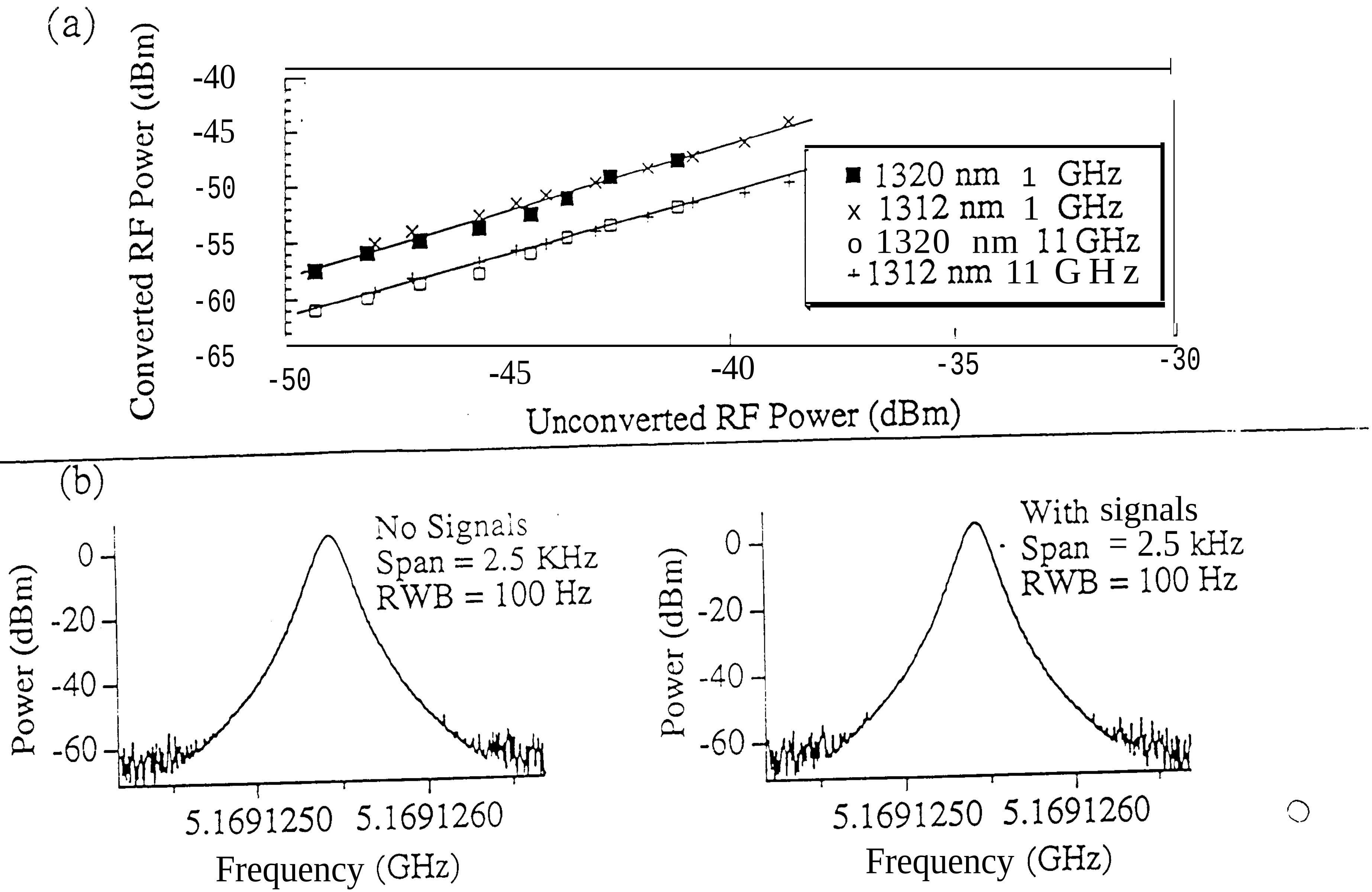
(a)
Converted RF Power (dBm)
-40
-45
-50
-55
-60
-65
-50
-45
-40
-35
-30
Unconverted RF Power (dBm)
1320 nm 1 GHz
x 1312 nm 1 GHz
o 1320 nm 11 GHz
+ 1312 nm 11 GHz
(b)
Power (dBm)
0
-20
-40
-60
No Signals
Span = 2.5 KHz
RWB = 100 Hz
5.1691250
5.1691260
Frequency (GHz)
Power (dBm)
0
-20
-40
-60
With signals
Span = 2.5 kHz
RWB = 100 Hz
5.1691250
5.1691260
Frequency (GHz)

Figure 3